A Cross-sectional study of prosodic sensitivity and reading difficulties

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Abstract

In this cross-sectional study, we explore the relationship between prosodic sensitivity (supra-segmental phonology) and phonological awareness (segmental phonology) and investigate whether a group of poor readers display significant supra-segmental phonological deficits in comparison to chronological-age matched controls and younger, reading-age matched controls. Phonological awareness assessments were administered along with a battery of prosodic sensitivity assessments drawn from recent literature. The results showed that poor readers were outperformed by their chronological-age matched counterparts on all measures of prosodic sensitivity. A significant main effect of group was found on the revised stress mispronunciations task and the stress assignment task from the prosodic assessment battery, the former of which remained even after controlling for individual differences in receptive vocabulary and measures of phonological awareness. Significant relationships were also found between measures of prosodic sensitivity and phonological awareness (especially phoneme awareness). These findings emphasise the importance of both segmental and supra-segmental phonological skills in children's reading development.

A Cross-Sectional Study of Prosodic Sensitivity and Reading Difficulties.

One of the most popular and widely accepted explanations of the cause of reading difficulties is the phonological coding deficit theory (Vellutino & Fletcher, 2005) which argues, in line with the phonological representations hypothesis (Snowling, 2000), that children with severe reading impairment are thought to have underspecified phonological representations of words, which compromise their ability to acquire phonological processing skills, alphabetic knowledge, decoding skills, and orthographic awareness (Vellutino & Fletcher, 2005).

The link between phonological processing skills and reading development has been well documented. For instance, rhyme awareness (a component of phonological awareness) has been found to predict children's reading and spelling development (e.g. Bryant, 1998) and has been implicated in models of typical reading development (e.g. Goswami & Bryant, 1990; Ziegler & Goswami, 2005). Strong relationships have also been found between phoneme awareness and reading development; phoneme awareness seems to facilitate the segmentation of words during decoding, which is a key skill related to successful reading development (Muter, Hulme, Snowling, & Taylor, 1998). While the relatedness of rhyme awareness and phoneme awareness and the predictability of each in children's reading development has been disputed (see Muter et al., 1998; Hulme, Muter, & Snowling, 1998; Bryant, 1998; Macmillan, 2002) there is a general acceptance that both of these phonological skills are strongly related to reading proficiency (Anthony & Lonigan, 2004).

Typical assessments of rhyme and phoneme awareness are primarily concerned with the separable sound segments of spoken language; this has been referred to as 'segmental phonology'. 'Supra-segmental' phonology on the other hand, carries information across multiple segments and is primarily concerned with the overarching patterns or elements of the speech stream, such as the prosodic features of speech (i.e. stress, intonation, timing, and rhythm). In the literature, the role of phonological awareness (segmental phonology) in reading development has received a great deal of attention and is well established (see Snowling, 2000 for review). However, less is known about the role of prosodic sensitivity (supra-segmental phonology) in children's reading development, although this topic area is gaining increasing interest in the recent literature (see Wade-Woolley & Wood, 2006; Wood, Wade-Woolley, & Holliman, 2009). The current study sought to investigate the relationship between segmental and supra-segmental (or prosodic) sensitivity in children's reading development, and explore whether a sample of children identified and classified as 'poor readers' display significant prosodic sensitivity deficits in comparison to a group of age-level and reading-level controls.

Prosodic Sensitivity, Phonological Awareness, and Reading

Goswami, Gerson, and Astruc (2009, p.1) point out that, "to date, the contributions made by prosodic sensitivity to reading development have largely been explored from the perspective of reading fluency and reading comprehension rather than phonological awareness and decoding". For instance, Miller and Schwanenflugel (2008) assessed prosody by audio recording children's oral reading, converting it to a .wav file, and then scoring their reading for pausing and intonation (two aspects of prosody) using a speech software package. Prosody was found to predict unique variance in reading comprehension and in reading fluency after controlling for word reading. Such findings have been replicated in other studies that have measured prosodic sensitivity in this way (e.g. Ravid & Mashraki, 2007; Schwanenflugel, Hamilton, Kuhn, Wisenbaker, &

2004). To explain such findings, it has been argued that prosodic skills may link together fluency and comprehension; that is, an individual who is able to read with attention to prosody is likely to be a fluent reader, be able to apply syntactic roles, and understand what is being read (Kuhn & Stahl, 2003). Schwanenflugel et al. (2004) also argued that proficient decoding skills should free up attention resources that can be made available to prosodic processing, that might add something more to comprehension processes.

In another related study, Whalley and Hansen (2006) assessed prosody in a group of eight to ten-year-olds at both the phrasal level (using the 'Deedee task') and at the word level (using the 'compound noun task'). The 'DEEdee task' assessed whether children could match a spoken phrase (e.g. Humpty Dumpty) with the correct Deedee phrase which was matched in terms of its intonation and prosodic patterns and the 'compound nouns task' assessed whether children could accurately identify the correct graphic by discriminating between two similarly sounding phrases, one of which was a noun phrase and the other of which was a compound noun (e.g. chocolate, cake, and honey, with chocolate-cake, and honey), which only differed in terms of their prosodic features. Phrase-level prosody was found to predict unique variance in children's decoding and reading comprehension and word-level prosody was found to predict unique variance in children's word reading. To explain these findings, Whalley and Hansen (2006) argued that prosody sensitivity may enable the individual to arrange, segment, and chunk spoken language into syntactically comprehensible units, which will reduce memory load and signify the more relevant aspects (comprehension). Kitzen (2002) also argued that prosodic sensitivity (to stress in particular) may help to clarify meaning and support comprehension because the location of stress can discriminate between nouns and verbs (e.g. PERmit and perMIT), and between compound nouns and noun phrases (e.g. BLACKbird and black BIRD).

Only a handful of studies have investigated the relationship between prosodic sensitivity and word reading from a decoding or phonological awareness perspective. For instance, Wood (2006) developed the ‘stress mispronunciations task’ to assess children’s sensitivity to stress in spoken language in a group of beginning readers. In this task, target words were mispronounced so that the stress fell on the ‘wrong’ syllable. To succeed at this task, children had to recover the correct stress in order to match the stored lexical code and identify the correct item from a choice of four pictures provided. As anticipated, performance on this task was found to be significantly related to reading development. In a similar study, Holliman, Wood, and Sheehy (2008) adopted the stress mispronunciations task from Wood (2006) and found that prosodic sensitivity was able to predict unique variance in word reading after controlling for age, vocabulary, and phonological awareness. The relationship between prosodic sensitivity (using an improved version of the stress mispronunciations task) and reading has also been demonstrated in other recent studies (e.g. Holliman, Wood, & Sheehy, in press; Authors, submitted).

To explain such findings, Wood argued in accordance with Chiat (1983) that phonemes and especially vowels in stressed syllables are easier to identify than when they occur in unstressed syllables, particularly as often unstressed syllables contain a reduced vowel (e.g. a schwa). As a result, an individual with greater sensitivity to stress in spoken language would have an increased potential to decode words on a phonemic basis during reading, and we know that phonemic awareness is linked to successful reading development. Another explanation is that an infant will typically find it difficult to break the speech stream down into smaller segments (identifiable words) because the speech stream is continuous and has few audible pauses between words. As English is a stress-timed language (with an equal number of time elapses between stressed syllables) and because stressed syllables mark the beginning of an estimated 85% of lexical words, excluding function words (Cutler and Carter, 1987) an individual who is more sensitive to stress would have an increased potential to identify words and word boundaries (Cutler, 1994; Cutler & Norris, 1988), and spoken word recognition skills have also been linked to successful reading development (e.g. Metsala, 1997).

Another potential explanation was formed as a result of Scott's (1998) observation that amplitude peaks in the speech signal correspond to vowel location in words. Goswami et al. (2002) applied this observation to the reading development field to argue that an individual that is more sensitive to these acoustic beats in spoken language (comparable to stress and intonation in terms of speech rhythm) would be better equipped to identify vowels in spoken words and would have an increased potential to identify onset rhyme boundaries, which have been discussed in models of typical reading development (Goswami & Bryant, 1990). Goswami et al., found, as expected, that dyslexic children displayed significant deficits in beat perception in comparison to their non-dyslexic counterparts. However, no significant differences were reported between the dyslexic children and the reading-level controls, which is suggestive of a 'maturational lag' as opposed to a specific deficit. Other studies have also provided support for a maturational lag rather than a specific deficit in the processing of speech rhythm or prosody in poor readers (Wood & Terrell, 1998), dyslexic children (Goswami et al, 2009; Richardson, Thomson, Scott, & Goswami,

2004) and children with specific language impairment (Corriveau, Pasquini, & Goswami, 2007).

In summary, there is increasing empirical evidence to suggest that prosodic sensitivity is related to reading and that it is predictive of reading after accounting for individual differences in phonological awareness. However, few studies (if any) to date have employed a comprehensive battery of prosodic sensitivity measures to assess the different components of prosody. Many group comparison studies also fail to include a reading-age matched control group in addition to chronological-age matched controls, which is important in determining whether any observed prosodic sensitivity deficits are an artefact of reading experience.

The purpose of this study therefore is to administer a battery of prosodic sensitivity assessments drawn from the recent literature to a group of children identified as ‘poor readers’, a chronological-age matched control group, and a reading-age matched control group, and to explore whether the ‘poor readers’ display significant prosodic sensitivity deficits in comparison to both control groups, and on which prosodic sensitivity measures. The question of whether ‘poor readers’ display deficits on all aspects of prosody (on all tasks) remain relatively unexplored. It will also be of interest to see how well a range of prosodic sensitivity measures (supra-segmental phonology) relate to measures of phonological awareness (segmental phonology).

To account for a range of prosodic sensitivity measures, four different assessments from the recent literature were included in this study; *The Revised Stress Mispronunciations Task* (Holliman et al. in press), *The Stress Assignment Task* (Wade-Woolley, 2007), *The Compound Noun Task* (Whalley & Hansen, 2006), and *The DEEdee Task* (Whalley & Hansen, 2006).

There were two key questions that were explored in this study:

1. Are there significant group differences between the 'poor readers', the chronological-age matched controls, and the reading-age matched controls in terms of their prosodic sensitivity, and do differences remain after controlling for receptive vocabulary, rhyme awareness, and phoneme awareness?
2. How do the various measures of prosodic sensitivity (supra-segmental phonology) relate to measures of segmental phonology?

Method

Participants

Fourteen children identified as poor readers were recruited from a single combined school in Buckinghamshire, UK. Their 'poor reader' status was based on them having a word reading age equivalent and a digit span (short term memory) age equivalent at least two years behind their chronological age, as indicated by the British Ability Scales II word reading subtest (Elliot, Smith, & McUlloch, 1996) and the digit span subtest from the British Ability Scales II (Elliot et al., 1996). It was felt necessary to include a digit span assessment in addition to a reading assessment in the screening process due to the strong relationship observed in the literature between short-term memory deficits and reading difficulties; for instance, Snowling (2000, p.35) noted that "perhaps the most consistently reported area of difficulty for dyslexic people is in short-term memory" and this is particularly evident on measures such as the digit span test (Hulme, Newton, Cowan, Stuart, & Brown, 1999). Fourteen age-matched controls and fourteen reading matched controls were obtained from the same combined school. Children with extremely high or low reading or digit span scores were excluded from the data in order to obtain well-matched control groups.

Table 1 below shows the mean and standard deviation of the age, reading raw scores, digit span raw scores, and vocabulary standard scores of the poor readers, the age-matched controls, and the reading-matched controls.

It can be seen from Table 1 that the poor readers (males *n* = 7, females *n* = 7) and the chronological-age matched controls (males *n* = 6, females *n* = 8) are well-matched on age with only a one-month difference between them and a similar standard deviation; the difference in age was not significant, $F(1, 26) = 0.065$, $p = 0.801$. The poor readers group and the reading-age matched controls (males *n* = 9, females *n* = 5) are well-matched on their reading raw scores, although the control group has a larger standard deviation; the difference in reading ability was not significant, $F(1, 26) = 0.029$, $p = 0.866$. These groups were also well-matched on their digit span raw scores, although once again, there was a larger standard deviation in the control group; the difference in short-term memory was not significant, $F(1, 26) = 0.297$, $p = 0.590$. Additionally, the poor readers had a mean standardised vocabulary score of 92.86 (*SD* = 5.93) which falls in the 'lower' part of the 'average score' range. The chronological-age matched controls had a mean standardised vocabulary score of 99.21 (*SD* = 10.91) which falls in the 'average score' range. Lastly, the reading-age matched controls had a mean standardised vocabulary score of 107.14 (*SD* = 10.53) which falls in the 'higher' part of the 'average score' range. All participating children in this study had English as their first language and were approached to participate only once both their parents and head-teachers had provided informed consent to take part.

Test Battery

Word Reading and Digit Span Test. Word reading accuracy was measured using the British Ability Scales II word reading subtest (Elliot, Smith, & McUlloch, 1996). Children had to accurately read out loud as many words as they could to the administrator from a possible list of ninety words. To obtain a simple measure of short-term memory ability, the digit span subtest from the British Ability Scales II (Elliot et al., 1996) was used. Children had to repeat a series of number sequences in the correct order back to the administrator. The measures of word reading accuracy and short-term memory were used for group matching purposes.

Vocabulary. The British Picture Vocabulary Scales II (Dunn, Dunn, Whetton & Burley, 1997) was used to obtain a measure of children's receptive vocabulary. Children had to accurately identify a single picture from a choice of four pictures that best illustrated the word spoken by the administrator.

Phonological Awareness (Rhyme Detection and Phoneme Deletion). To obtain a measure of children's sensitivity to rhyme, the rhyme detection subtest of the Phonological Assessment Battery (PhAB; Frederickson, Frith, & Reason, 1997) was used. After hearing three words spoken by the administrator, children had to accurately repeat the two rhyming words from the three provided. To obtain a measure of phoneme awareness, the phoneme deletion task (Wood, 1999) was used. Children had to repeat a word back to the administrator without either the first phoneme (e.g. "many" would become "any") or the last phoneme (e.g. "paint" would become "pain") depending on what subtest they were undertaking. Children attempted twelve words from each subtest so a score from twenty-four was obtained.

Prosody Assessment 1: The Revised Stress Mispronunciations Task. Prosodic sensitivity was measured using the revised stress mispronunciations task from Holliman et al. (in press). Children heard pre-recorded bisyllabic words through a speaker and then had to identify that target word from a choice of four pictures available. All distractor items were matched as closely as possible on their frequency of use to the target item. All of the target items, when pronounced correctly, carried primary lexical stress on the first syllable with a reduced vowel in the second syllable. However, for this task, the stress in the words spoken by the administrator was reversed in each trial so that the vowel in the first syllable was reduced and the vowel in the second syllable was fully articulated, e.g. the word “singer” (‘sɪŋə) would be pronounced “sn’ger” (səŋ‘ɜː).

To solve this task, children need to be sensitive to the fact that the stress of the word has been manipulated and need to recover the stress in order to identify the target item and in this sense, it is a stress sensitivity measure. Following a single practice item, children attempted eighteen test items so a score from eighteen was obtained. See Appendix A for the items used in this task.

Prosody Assessment 2: The Stress Assignment Task. A further measure of prosody was obtained from the stress assignment task (Wade-Woolley (2007). In this task, children heard a pre-recorded single word through a speaker (e.g. direct). They then had to repeat this word out loud and then clap on the part of the word with the strongest beat (the stressed syllable). For example, in the word “direct”, which can be split into two syllables, a clap on the “rect” part of this word would be a correct response because this is where the stress falls in the normal pronunciation of this word. It should be noted that there were originally thirty test items in the stress assignment task, but to minimise the length of testing period, only the first fifteen items were chosen to indicate ability on this task following the two practice items. See Appendix B for the items used in this task.

Prosody Assessment 3: The Compound Noun Task. To assess prosodic sensitivity at the word level, the compound noun task from Whalley and Hansen (2006) was used (see Whalley and Hansen for a detailed description of this task). Children heard either a compound noun (e.g. bow-tie and shoes) or a noun phrases (e.g. bow, tie and shoes) that had been pre-recorded and sounded through a speaker and then had to select the appropriate graphic which corresponded with the words from a choice of two pictures available. For example, for the test item "bow-tie and shoes", the graphic with two items (e.g. a bow-tie and shoes) would be the correct answer and the graphic with three items (e.g. a bow, tie, and shoes) would be the incorrect response. To solve this task, children had to be sensitive to the prosodic features of the words and use this sensitivity to discriminate between compound nouns and noun phrases. Both the compound noun and noun phrase scenarios were used throughout the task and there were twenty test items altogether; thus, children obtained a score out of twenty.

Prosody Assessment 4: The DEEdee Task. To assess prosodic sensitivity at the phrasal level, the DEEdee task from Whalley and Hansen (2006) was used (see Whalley and Hansen for a detailed description of this task). Children heard a pre-recorded phrase, which took the form of a cartoon title (e.g. "The Simpsons"). This was followed by two Deedee phrases, one of which retained the prosodic structure of the original phrase and one of which did not and children had to indicate which of the two phrases matched the original phrase (e.g. for "The Simpsons" example above, "deeDEEdee" would be a correct answer and "DEEdeeDEE" would be an incorrect answer). To solve this task, children had to be sensitive to the prosodic features of speech and non-speech sounds and the nature of this task eliminated the potential of phonemic information. Following two practice items, there were eighteen test items, so children obtained a score out of eighteen.

Procedure

The assessments were presented in a quasi-randomised order over three sessions to minimise the length of testing period. The first session always consisted of the word reading test and digit span test only. This was important for screening purposes so that children could be allocated to particular groups based on their scores. This was followed by two batches of assessments, one of which included the computerised tasks (i.e. the revised stress mispronunciations task, the Deedee task, and the compound nouns task) and the other consisted of the non-computerised tasks (i.e. the phoneme deletion task, the rhyme detection task, the stress assignment task, and the measure of vocabulary). The order of these batches was randomised, and the order of presentation of tasks within each batch was also randomised. Participants performed individually and completed the assessment battery over a two-week period.

Results

Table 2 shows the mean and standard deviation scores for the poor readers, the chronological-age matched controls, and the reading-age matched controls on the measures of phonological awareness and prosody.

It can be seen from Table 2 that the chronological-age matched controls outperformed both the poor readers and the reading-age matched controls on all measures of phonological awareness and prosody, as expected. The chronological-age matched controls scored in the upper range on all tasks with the exception of the stress assignment task where they obtained a score in the middle range. Interestingly, the reading-age matched controls obtained a higher score on the rhyme awareness measure (mean = 17.43, SD = 3.44) than the poor readers (mean = 13.29, SD = 5.89), although similar scores were obtained between the two groups on the phoneme deletion measure. With respect to the prosody assessments, the reading-age matched controls obtained a higher score on the revised stress mispronunciations task (mean = 14.36, SD = 1.86) than the poor readers (mean = 12.93, SD = 2.81), but these two groups scored similarly on the remaining three assessments of prosodic sensitivity. Moreover, an inspection of the alpha values indicates that while the stress assignment task and the compound noun task have acceptable internal reliabilities ($\alpha = 0.73$ and $\alpha = 0.83$ respectively), the Deedee task has poor internal reliability ($\alpha = 0.37$), so analyses including this measure should be treated with caution. While the internal reliability of the revised stress mispronunciations task was also relatively low with this sample ($\alpha = 0.6$), a recent study (Holliman et al. in press) using a much larger sample found the internal reliability of this task to be 0.81.

1. *Are there significant group differences between the poor readers, the chronological-age matched controls, and the reading-age matched controls in terms of their prosodic sensitivity, and do differences remain after controlling for receptive vocabulary, rhyme awareness, and phoneme awareness?*

The data were inspected to ensure they met the assumptions for an analysis of variance/covariance. The two phonological awareness measures (rhyme detection and phoneme deletion) were negatively skewed. To correct this, the scores were reflected and a logarithm transformation was used. A series of analyses of variance were conducted to test whether there were any significant differences between the poor readers, age-matched controls, and reading-age matched controls on the measures of prosodic sensitivity.

A significant main effect of group was found on the revised stress mispronunciations task from the prosodic test battery, $F(2, 39) = 5.790$, $p = 0.006$, partial $\eta^2 = 0.229$. A post hoc analysis using Tukey LSD revealed that there were significant group differences between the poor readers and the chronological-age matched controls ($p = 0.002$), but not between poor readers and the reading-age matched controls ($p = 0.089$). A significant main effect of group was also found on the stress assignment task from the prosodic test battery, $F(2, 39) = 3.365$, $p = 0.045$, partial $\eta^2 = 0.147$. A post hoc analysis using Tukey LSD revealed that there were significant group differences between the poor readers and the chronological-age matched controls ($p = 0.035$), but not between poor readers and the reading-age matched controls ($p = 0.904$). However, there were no significant main effects of group on the noun task, $F(2, 39) = 2.043$, $p = 0.143$, nor the Deedee task from the prosodic test battery, $F(2, 39) = 1.723$, $p = 0.192$. Therefore, the noun task and the Deedee were not included in any of the subsequent analyses of covariance.

Due to the fact that a significant main effect of group was found on the measures of vocabulary, $F(2, 39) = 8.112$, $p = 0.001$, partial $\eta^2 = 0.294$, rhyme awareness, $F(2, 39) = 4.873$, $p = 0.013$, partial $\eta^2 = 0.2$, and phoneme awareness, $F(2, 39) = 6.652$, $p = 0.003$, partial $\eta^2 = 0.254$, these variables were controlled for at different stages in the subsequent Analyses of Covariance.

The results of the ANCOVA showed that after controlling for receptive vocabulary, there was a main effect of group on the children’s overall performance on the revised stress mispronunciations task, $F(2, 38) = 5.945$, $p = 0.006$, partial $\eta^2 = 0.238$. A post hoc analysis using Tukey LSD revealed that there were significant group differences between the poor readers and the chronological-age matched controls ($p =$

0.004) and between the poor readers and the reading-age matched controls ($p = 0.018$). However, no significant main effect of group was found on the stress assignment task after controlling for receptive vocabulary, $F(2, 38) = 1.877$, $p = 0.167$, so the stress assignment task was not included in any of the subsequent analyses of covariance.

After controlling for receptive vocabulary and rhyme awareness, there was still a main effect of group on the children's overall performance on the revised stress mispronunciations task, $F(2, 37) = 3.463$, $p = 0.042$, partial $\eta^2 = 0.158$. A post hoc analysis using Tukey LSD revealed that there were significant group differences between the poor readers and the chronological-age matched controls ($p = 0.016$), but not between poor readers and the reading-age matched controls ($p = 0.08$). The same pattern of results was obtained when phoneme awareness was entered instead of rhyme awareness at Step 2. However, after controlling for receptive vocabulary, rhyme awareness, and phoneme awareness, there was no longer a significant main effect of group on children's performance on the revised stress mispronunciations task, $F(2, 36) = 2.990$, $p = 0.063$.

2. How do the various measures of prosodic sensitivity (supra-segmental phonology) relate to measures of segmental phonology and reading in a group of poor readers?

To investigate the relationship between prosodic sensitivity, phonological awareness and reading, a correlation matrix were inspected, which included the age-matched children only; thus, the 'poor readers' group and the chronological-age matched controls. Table 3 shows the correlation matrix on all measures of age, vocabulary, prosody, phonological awareness, and reading.

It can be seen from Table 3 that phoneme awareness ($r = 0.770$, $p < 0.001$) and rhyme awareness ($r = 0.702$, $p < 0.001$) were significantly correlated with reading, as expected. The revised stress mispronunciations task was significantly related to phoneme awareness ($r = 0.383$, $p = 0.044$) and reading ($r = 0.484$, $p = 0.009$), but not rhyme awareness. The stress assignment task was also found to be significantly related to phoneme awareness ($r = 0.418$, $p = 0.027$) and reading ($r = 0.531$, $p = 0.004$), but not rhyme awareness. Furthermore, the noun task was found to be significantly related to reading ($r = 0.445$, $p = 0.018$) while the Deedee task was found to be significantly associated with phoneme awareness ($r = 0.446$, $p = 0.017$), rhyme awareness ($r = 0.483$, $p = 0.009$), and reading ($r = 0.425$, $p = 0.024$). Generally, there were significant associations between prosodic sensitivity, phonological awareness (especially phoneme awareness), and reading attainment.

Discussion

The overall findings from this study emphasise the importance of prosodic sensitivity in children's reading development. Chronological-age matched controls outperformed the poor readers on all measures of prosodic sensitivity. However, from the comprehensive battery of prosodic assessments, the results yield a significant main effect of group on the stress mispronunciations task and the stress assignment task only, the former of which remained after controlling for receptive vocabulary and rhyme (or phoneme) awareness. Further post hoc analyses revealed no significant group differences between the poor readers and the reading-age matched controls, which suggests that the prosodic sensitivity deficits witnessed in children with reading difficulties are more likely to be representative of a maturational lag in development as opposed to a specific deficit, which is consistent with the findings from Wood and

Terrell (1998), Goswami et al. (2009), Richardson et al. (2004), and Corriveau et al. (2007) noted earlier.

Moreover, prosodic sensitivity (supra-segmental phonology) was found to be significantly correlated with phonological awareness (segmental phonology). This relationship was anticipated by Wood et al. (2009). To explain these relationships, the authors speculate that sensitivity to speech rhythm (supra-segmental phonology) is an important reading-related skill because it helps bind with phonological processing (segmental phonology). Children with proficient speech rhythm sensitivity would find these skills to be more easily transferable to phonological processing, which would allow for an increased capacity and potential to decode words. Recall that Wood (2006) also argued in line with Chiat (1983) that the identification of phonemes is easier in stressed syllables and therefore a child who is more sensitive to stress might have an increased potential to decode words phonemically. This idea was supported by the significant relationships observed in this study between performance on the phoneme deletion task and three of the four measures of prosodic sensitivity. There was less support for the relationship between prosodic sensitivity and rhyme awareness in this study.

However, there are some limitations to this study. Firstly, while these findings may contribute to our understandings regarding the role of segmental phonology and supra-segmental phonology in reading, the interpretations offered here should be treated with caution, especially due to the limited sample size in this study. More empirical evidence is required to support these claims. Moreover, one of the prosodic sensitivity assessments in this study, the Deedee task, had poor internal reliability and therefore the findings surrounding this task should be treated with caution. Nevertheless, this study is the first to employ a comprehensive battery of prosodic sensitivity measures to investigate whether poor readers display significant prosodic sensitivity deficits in comparison to both age-level and reading-level controls, and to investigate the relationship between segmental and supra-segmental phonological skills.

It is perhaps noteworthy that the two significant main effects in this study were found on the stress mispronunciations task and the stress assignment task, both of which assessed prosodic sensitivity at the 'word level'. Moreover, the word-level assessments of prosody in this study were more strongly related to the word reading assessment than the phrase-level assessment of prosody (i.e. the Deedee task). This was in line with the findings from Whalley and Hansen (2006) who also found that word-level prosody was more strongly related to word reading, while phrase-level prosody was more strongly related to comprehension. On the basis of these findings it seems plausible that prosodic sensitivity at different levels may be related to different aspects of the reading development process. However, few (if any) studies have assessed the relationship between the different levels of prosody (e.g. word-level, phrase-level, and sentence-level) and literacy in a single study. Further research might also investigate how the different components of prosody (i.e. stress, intonation, and timing) interact with the different levels of prosody; this has not been done in the literature.

Conclusion

The findings from this study suggest that the relationship between prosodic sensitivity and reading development. Prosodic sensitivity and sensitivity to stress in particular, provides reliable cues which help the individual to break up the speech stream into interpretable units (spoken word recognition), enhance phoneme identification (Wood, 2006), and facilitate the identification of onset rhyme boundaries

(Goswami et al., 2002) and these supra-segmental skills, when proficient, help map onto the individual's segmental phonology, enabling more transparent, comprehensive segmental awareness and more complete phonological representations of words. Sensitivity to prosody is implicated in successful reading development and should therefore be included into current models of successful reading development.

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Appendix A

Table A1. Phonetic transcription and word frequency per million for all target and distractor items.

Target Words and Freq	Phonetic Transcription	Stress Reverse Condition	Distractor Item 1 and Freq.	Distractor Item 2 and Freq.	Distractor Item 3 and Freq.
spider (93)	‘spaɪdə	spə'dɜ:	swinging (83)	snowman (62)	sandwich (83)
baker (93)	‘beɪkə	be'ɪkɜ:	beetles (83)	branches (93)	bottles (93)
barrel (10)	‘bærəl	bə'rel	bracelet (10)	burglars (10)	ballet (10)
builder (21)	‘bɪldə	bəl'dɜ:	blackbird (31)	biscuit (21)	bookcase (21)
butcher (41)	‘bʊtʃə	bə'tʃɜ:	baseball (52)	badgers (31)	boiling (52)
butter (175)	‘bʌtə	bə'tɜ:	breakfast (196)	bottle (186)	basket (186)
carrot (21)	‘kærət	kə'rɒt	clipboard (10)	cutting (10)	camel (21)
cleaner (83)	‘kli:nə	klə'nɜ:	crying (72)	counting (62)	cupboard (93)
cooker (31)	‘kʊkə	kə'kɜ:	carrots (31)	cowboy (31)	crayons (31)
jumper (114)	‘dʒʌmpə	dʒəm'pɜ:	jewels (114)	jolly (103)	jacket (93)
mirror (41)	‘mɪrə	mə'rɔ:	married (41)	mushrooms (31)	marbles (52)
painter (21)	‘pentə	pən'tɜ:	panda (31)	penguin (21)	peanuts (21)
parrot (83)	‘pærət	pə'rɒt	pattern (72)	pumpkin (62)	pocket (62)
plaster (52)	‘plɑ:stə	pləs'tɜ:	pencil (52)	penny (41)	pizza (41)
rubber (10)	‘rʌbə	rə'bɜ:	rhino (31)	raining (10)	robot (21)
ruler (10)	‘ru:lə	rə'lɜ:	rowing (10)	robin (31)	rainbow (21)
sailor (10)	‘seɪlə	sə'lɔ:	swimmer (10)	smiling (10)	scarecrow (21)
singer (10)	‘sɪŋə	səŋ'ɜ:	swordfish (10)	skateboard (10)	seagull (10)
tiger (52)	‘taɪgə	tə'gɜ:	tissue (31)	tractor (31)	twenty (31)

Notes: The word frequencies in parentheses are per million.

Appendix B

Table A2. Stimuli for the stress placement task

Practice					
1. below	be	**low**			
2. magazine	ma	ga	**zine**		
Test items					
1. analysis	a	**na**	ly	sis	
2. literature	**lit**	er	a	ture	
3. democratic	de	mo	**cra**	tic	
4. remember	re	**mem**	ber		
5. decision	de	**ci**	sion		
6. direct	di	**rect**			
7. approach	ap	**roach**			
8. appear	ap	**pear**			
9. international	in	ter	**na**	tion	al
10. equipment	e	**quip**	ment		
11. understand	un	der	**stand**		
12. activity	ac	**ti**	vi	ty	
13. answer	**an**	swer			
14. opportunity	op	por	**tu**	ni	ty
15. beautiful	**beau**	ti	ful		

Table 1.

Mean and standard deviation of the age, reading raw scores, digit span raw scores, and vocabulary standard scores of the poor readers group, chronological-age matched control group, and reading-age matched control group

		Age (months)	Reading (RS)	Digit Span (RS)	BPVS (SS)
Poor readers	Mean	126	47.86	20.21	92.86
(*n* = 14)	S.D.	6.84	8.68	4.08	5.93
Controls (Age)	Mean	125	70.5	23.43	99.21
(*n* = 14)	S.D.	6.51	9.16	3.65	10.91
Controls (Reading)	Mean	84	48.57	19.43	107.14
(*n* = 14)	S.D.	4.8	13.04	3.52	10.53

Table 2.

Summary statistics for the poor readers group (RD), the chronological-age matched controls (AMC), and the reading-age matched controls (RMC) on the measures of phonological awareness and prosody, along with the internal reliability of each test

		Rhyme /21 α = .92	Phoneme /24 α = .89	RSMT /18 α = .60	Stress Ass. /15 α = .73	Noun /20 α = .83	Deedee /18 α = .37
RD	Mean	13.29	17.64	12.93	6.14	16.07	11.5
	SD	5.89	3.18	2.81	2.57	3.91	2.35
AMC	Mean	18.21	21.71	15.71	8.71	18.07	13
	SD	4.42	2.02	1.64	3.87	3.17	2.45
RMC	Mean	17.43	17	14.36	6	15.5	11.57
	SD	3.44	6.89	1.86	2.75	3.48	2.44

Table 3.

Correlation matrix between prosody, age, vocabulary, phonological awareness, and reading for the age-matched children only (n = 28)

Variables	1	2	3	4	5	6	7	8	9
1. Age									
2. BPVS	.25								
3. Phoneme	.18	.29							
4. Rhyme	.4*	.57**	.64***						
5. RSMT	-.03	.27	.38*	.26					
6. Stress Ass.	.1	.41*	.42*	.31	.5**				
7. Noun	.07	.29	.3	.1	.29	.24			
8. Deedee	-.04	.39*	.45*	.48**	.17	.49**	.2		
9. Digit Span	.23	.35	.36	.47*	.22	.36	.05	.33	
10. Reading	.35	.53**	.77***	.7***	.48**	.53**	.45*	.43*	.5**

Notes: Age, Age; BPVS (RS), Vocabulary Raw Scores; Phoneme, Phoneme Deletion Task; Rhyme, Rhyme Detection Task; RSMT, Revised Stress Mispronunciations Task; Stress Ass., Stress Assignment Task; Noun, Noun Task; Deedee, Deedee Task; Digit Span, Digit Span Test Raw Scores; Reading, Word Reading Raw Scores.

*p<.05, **p<.01, ***p<.001